Virtual National Laboratory for Heavy Ion Fusion

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HIF News

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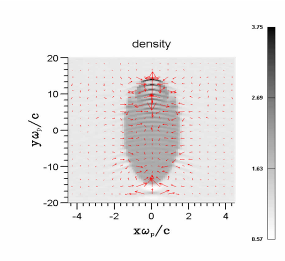
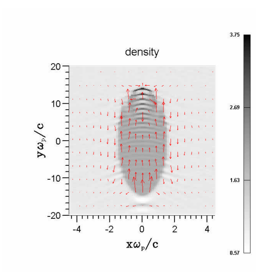
Nonlinear Charge and Current Neutralization for an Intense Ion Beam Pulse in a Background Plasma*

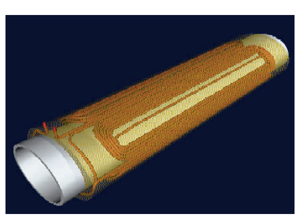
We have developed an analytic theory that predicts the degree of charge and current neutralization for a high-current finite-length ion beam propagating through a chamber filled with plasma of arbitrary density. The electric and magnetic fields generated by the ion beam are studied analytically for the nonlinear case where the plasma density approaches the beam density. Particle-in-cell simulations of current and charge neutralization agree well with the analytical results. An important conclusion is that the charge neutralization is essentially complete, even for very tenuous plasmas; under the assumption of nonrelativistic ion beams, with length much greater than both the beam radius and the plasma neutralization length. (The latter is the ratio of the beam velocity to the electron plasma frequency.) Current neutralization is usually much weaker than charge neutralization. Therefore, the magnetic pinching force dominates the electric force, so the beam ions are always pinched during quasi-steady-state beam propagation through the background plasma. Results, to be published in Physics of Plasmas, are shown for propagation in the y-direction, with beam length *15* c/ω_p; beam radius *1.5* c/ω_p; beam density equal to the background plasma density; and beam velocity *c/2*. Shown are electron density and the vector fields for the current (top) and the electric field (bottom). The excitation of plasma waves by the beam head is clearly seen. Both the current and electric field are localized near the beam edges as predicted by theory. – *Igor D. Kaganovich, and Ronald C. Davidson*



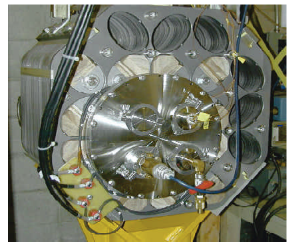


Pulsed quadrupole magnets developed

For HIF, and other non-DC magnetic applications, pulsed magnets offer high fields at lower cost than superconducting (SC) magnets, and at lower energy consumption than DC resistive magnets. They are compact and have a high degree of design flexibility. Though not feasible for the main magnetic transport in an IFE driver, they could prove desirable in some sections. These might include very-short-lattice-period transport, final focus in high neutron and radiation environments, beam steering and corrections between transport sections, and time dependent focusing.



Five pulsed elliptical quadrupole magnet prototypes, designed for an IRE magnetic focusing array, have been built and tested successfully at LBNL (See picture; a design description is at http://www-eng.lbl.gov/~shuman/HIF/THP159.pdf). One quadrupole has been pulsed over 80k times, at full current (4.4 kA, 3.0 kV). The remaining four have been simultaneously pulsed 10k times, at currents up to 4 kA. These four are assembled into a flux connecting iron core that can accommodate 21 quadrupoles, forming an array. They will soon be removed and installed into individual flux-return cores for HCX Phase I experiments. After HCX, they will be tested to end-of-life.

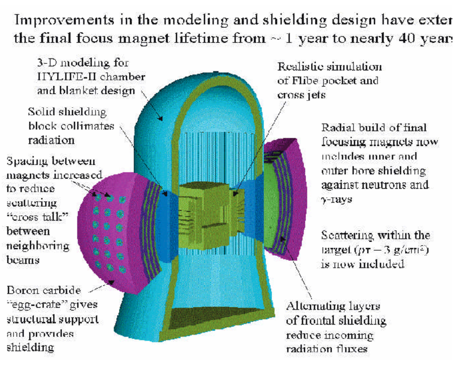


A set of large-bore pulsed-quadrupole and octupole magnets are now being designed for the Neutralized Beam Transport Experiment, NTX, and a short high field pulsed quadrupole is being designed as an alternative to the SC quadrupoles under development for HCX Phase II. – *Derek Shuman*

Improved neutron shielding of 72 beams into chamber

The recent trend for heavy-ion fusion has been to increase the number of beams in an effort to reduce the cost of the driver. While the number of beams has grown, currently available target designs still require small (<15º) array angles for the incoming beams. Although older designs such as HYLIFE-II, Osiris, and HIBALL called for ~30 cm of magnet shielding, these designs used 12-20 beams, and thus, such thick shields were relatively easy to accommodate. Calculations performed in 1999 suggested that reducing the magnet bore shielding to 5 cm would increase dose rates and neutron fluences experienced by the superconductor and insulation thereby reducing the magnet lifetime to <1 y.

Recently, we conducted a systematic study of the various shielding features and their importance to the overall problem. More than a dozen features were examined. Examples include the shielding thickness, composition, and location as well as the array angle, focusing length, beam clearances, and three-dimensional effects. In the end, a magnet shielding design was identified (see picture) that yielded a magnet lifetime in excess of 30 y. One key factor that helped extend the magnet lifetime was spreading the array to an angle of 28º.



Further work is needed to bring the shielding design into compliance with target requirements. Also, superconductor activation in the current design exceeds levels for disposal via shallow land burial. Magnet cooling requirements will be assessed in future work. – *Jeff Latkowski*

For comments about the content of the HIF News, contact Art Molvik (925)422-9817, or molvik1@llnl.gov.
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